

iGEM Program Overview



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International Genetically Engineered Machines Competition

Outline

- Overview of fundamental drivers
- How iGEM came to exist
- The goals of the program
- iGEM growth and success
- Reasons to participate
- Speculate on the future of iGEM and synthetic biology

R & D

What is biological research?

- Study of living things
 - Macro: description and classification of organisms
 - Molecular: description and classification of genomic data, proteome data, regulatory networks, signaling networks, etc.

Reverse Engineering

Reverse engineering is essentially science, using the scientific method.

Sciences such as biology and physics can be seen as reverse engineering of biological 'machines' and the physical world respectively.

Attempt to go backwards through the development cycle – “top down” approach

Source: wikipedia

Scientists hack

Tools of the trade

Classical

Restriction enzymes
Plasmids
Hybridization
PCR
DNA sequencing
Light microscopes, EM,
SEM
Pipettes, microtubes
uL volumes
Lab notebooks
Journal articles
Etc.

Refinements

Automated DNA sequencing
Software-based data analysis
and modeling
Parallelized, HTS experiments
nL or smaller volumes
Higher resolution vision – single
molecule, real time
Robots and computers
Internet-based data sharing, eg.
wikis, open access journals

Reverse engineering results in massive amounts of data

Systems biology attempts to integrate this and create comprehension to facilitate research and development

Easier to produce and collect data than to make sense of it.

We are just beginning to learn about microbial and molecular world.

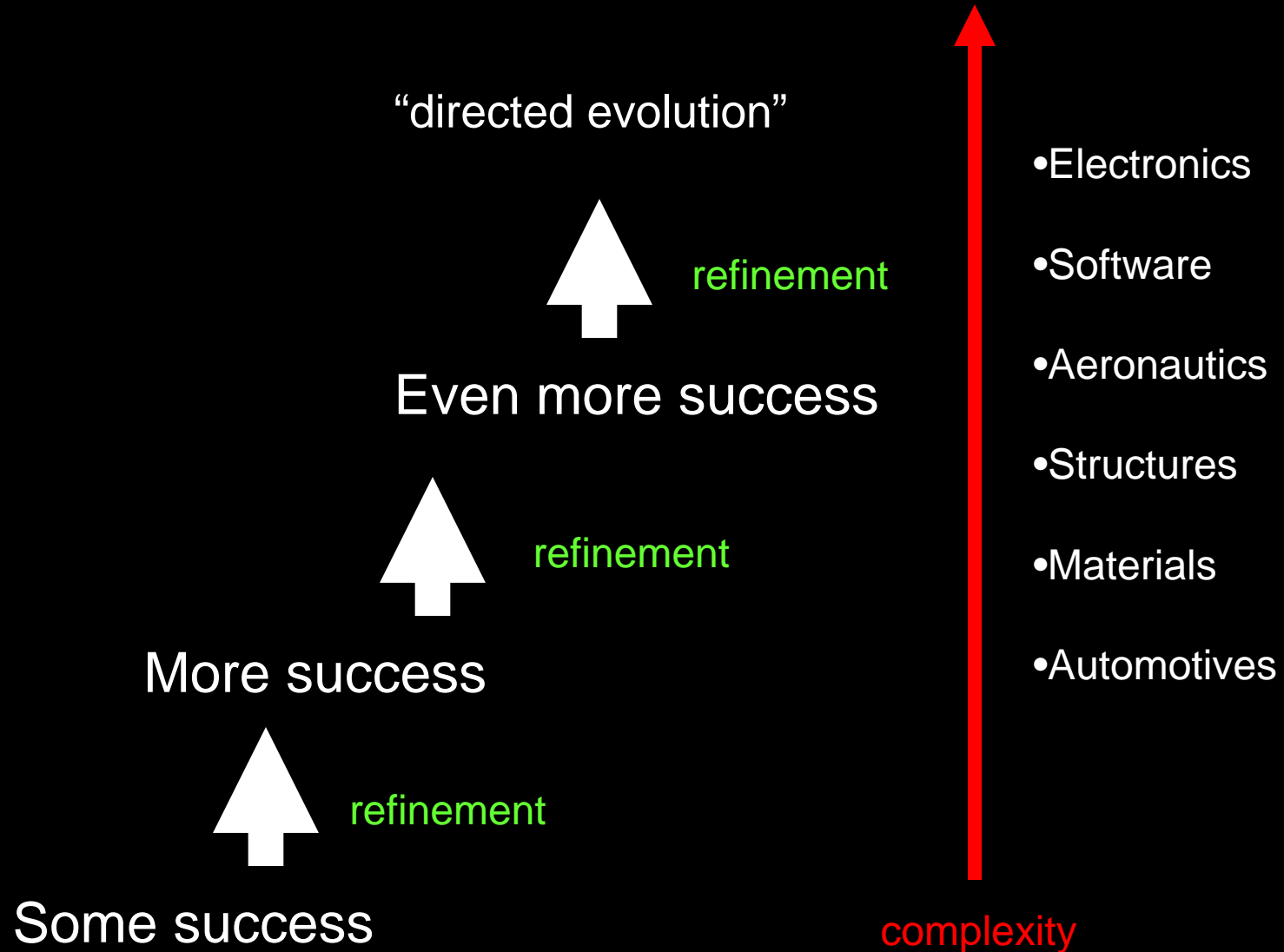
What is biological engineering?

In a word: Development

Very different mindset, culture, skills required to do development.

Not much exposure to development in most academic science settings.

Engineering Foundation



We need to engineer

- Apply knowledge gained from research to engineer the world around us
- Engineered structures and systems have defined characteristics, are dependable, make us feel in control
- Necessary to develop projects beyond the capabilities of the individual
- Today, almost everything around us is heavily engineered
- The one major exception is living organisms

To the engineer, past BE efforts inefficient

Struggle
Limited success
More struggle

Haphazard success

Problems compounded by proprietary IP

BE seen as “fuzzy”, risky, even *dangerous*



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Key question:

Can biological engineering be made more robust and reliable and easy?

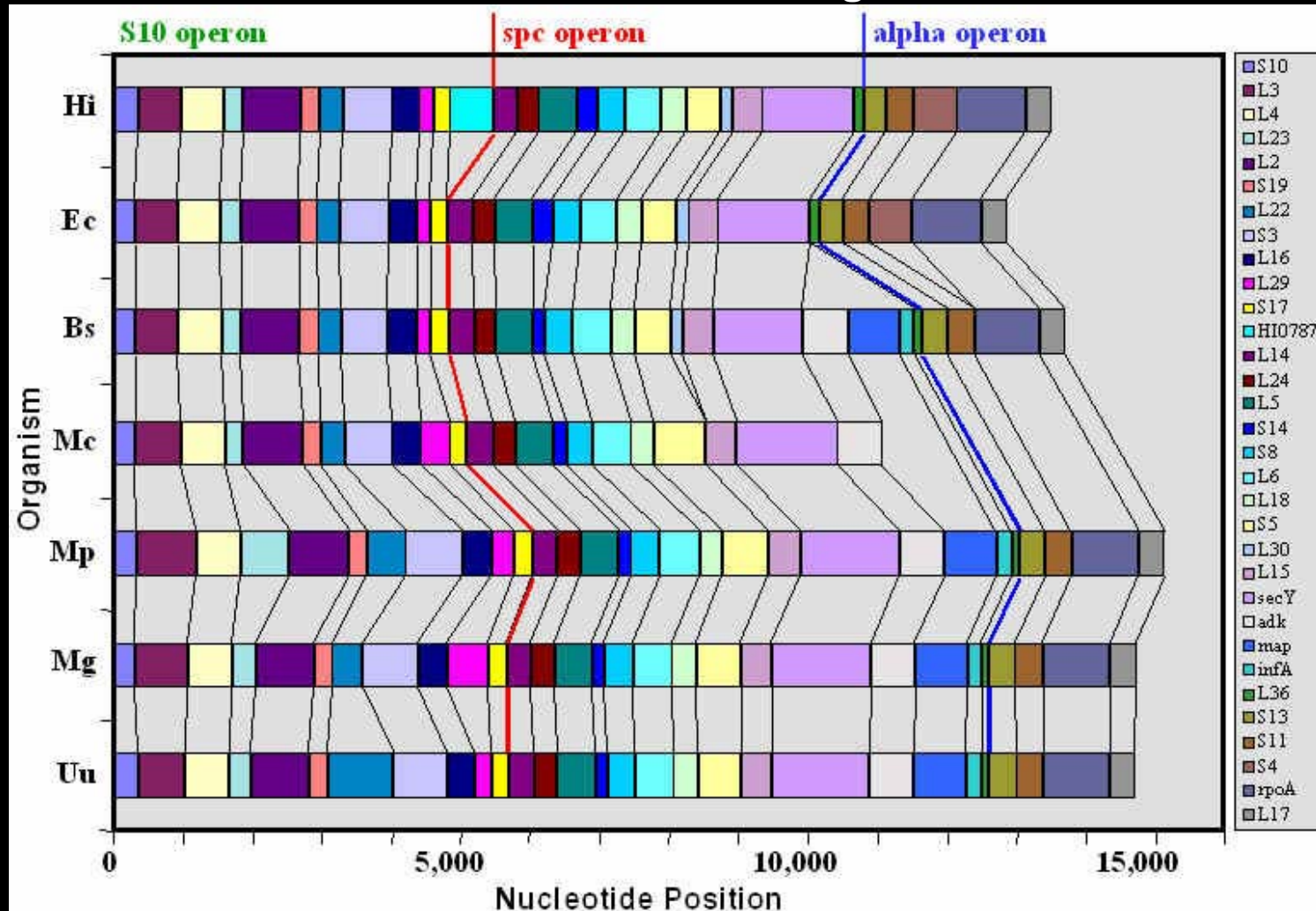
Synthetic Biology



- Founded on DNA synthesis
- DNA code can result in the creation and operation of virtually any biological molecule, process, bounded set of processes (organism), or ecology
- Ability to create DNA *de novo* results in a true programming language for biological machines

Existing genetic code is modular

Ribosomal Cluster Genome Organization



Problem:

We didn't write existing DNA code or the design the cellular processors on which it runs.

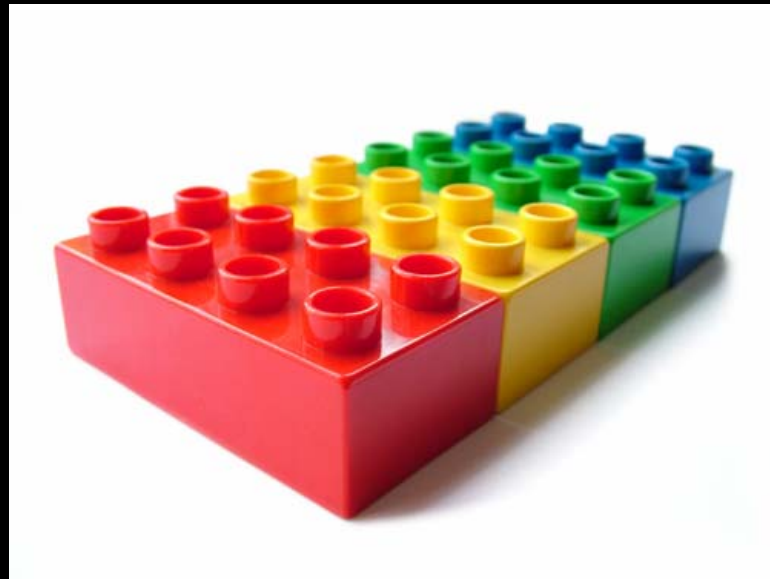
Evolved by natural selection, these programs and systems are selected for dynamic flexibility.

Not ideal for engineering purposes, which above all requires stable performance.

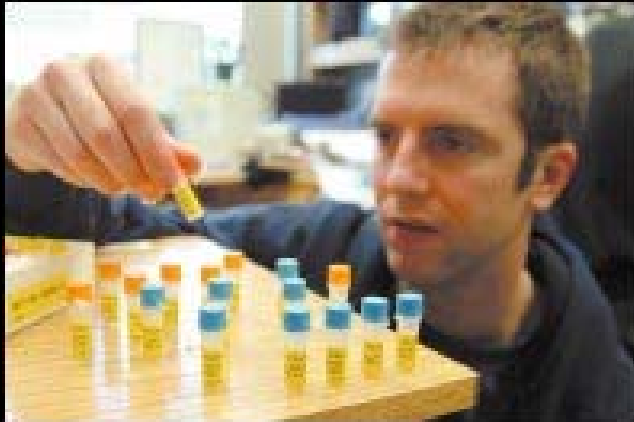
We can't *fully understand* natural biological systems.

Solution: make new modules

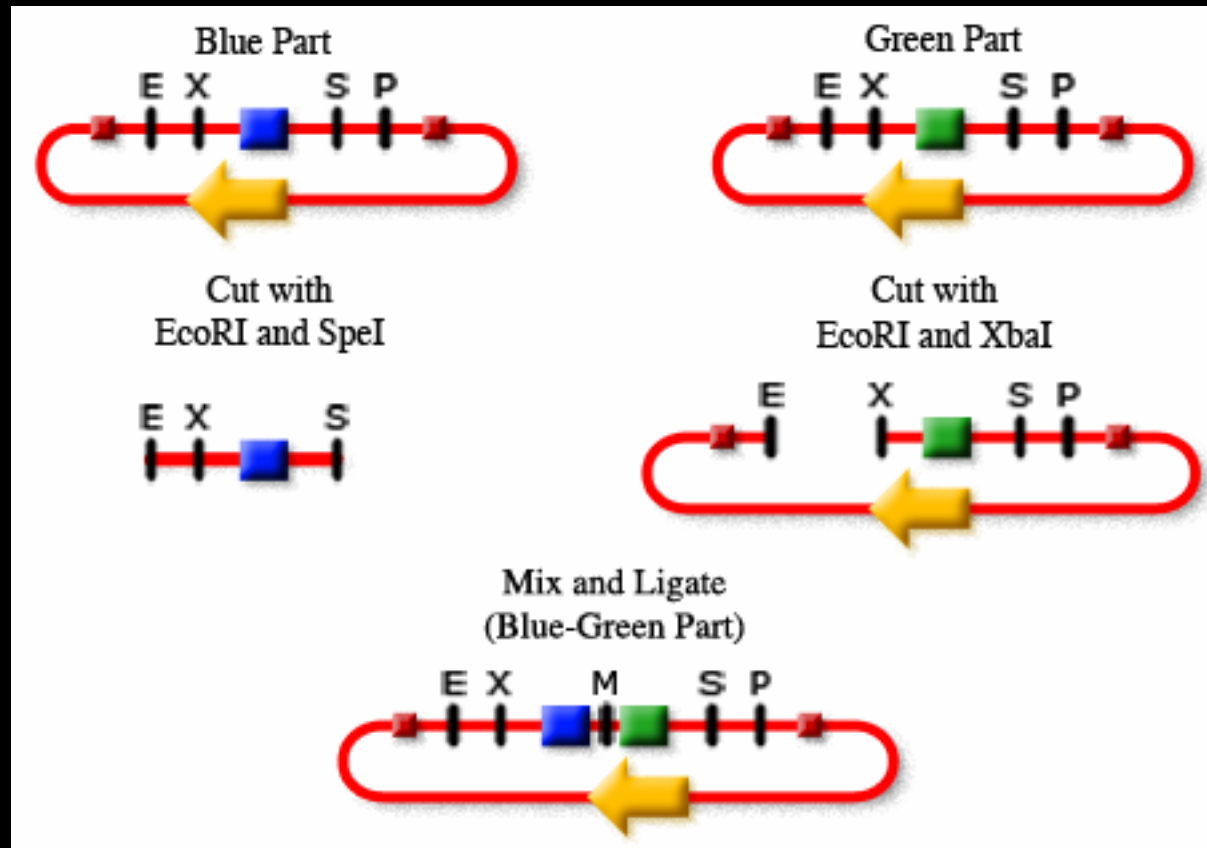
- Defined
- Multi-purpose
- Flexible
- Potential for unlimited applications



Inspiration for the “Bio-brick”

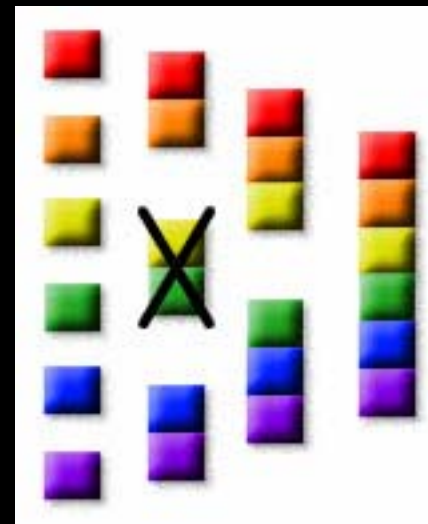
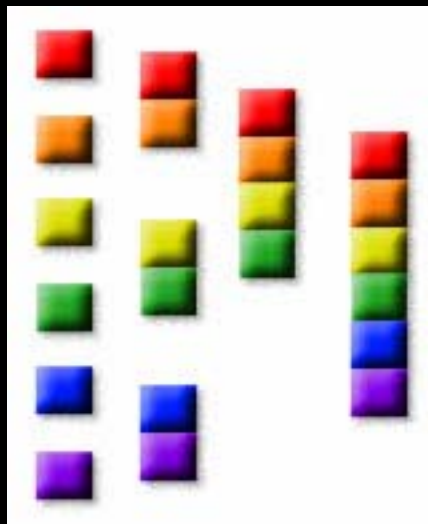


And a way to assemble them...



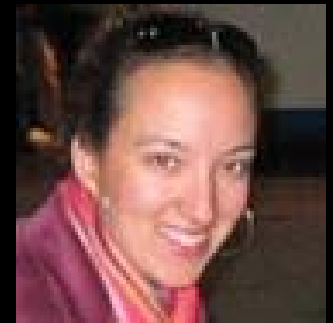
“standard assembly”

Rolling Assembly



Rolling standard assembly allows multiple assembly lines to be pursued to make the final product. This makes assemblies fault tolerant. Process is iterative and can be automated.

Robotic Bio-Brick Assembly



Alberta January 2007

Bio-Bricks allow:

- **Standardization**
 - Defined parts, with specifications, facilitate broad collaboration
- **De-coupling**
 - Complex problems can be broken into smaller problems, allowing parallel efforts
- **Abstraction**
 - Tiers complexity, permits specialization

Abstraction Hierarchy

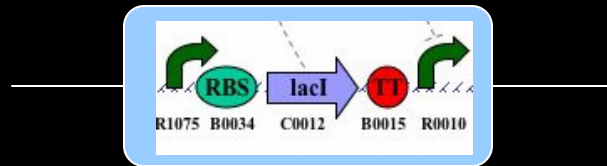
Systems



Multiple devices with a defined function



Device



Multiple biobricks with a defined function



Part



Basic biobrick, eg. protein coding region



DNA

atgtggagggtctgtatcatctattggactc

"Source code"

Approach:

1. Seed a library of parts
2. Encourage creativity

Use “open source”

- Consistent with academic principles
- Facilitates discussion and exchange
 - Lubricates dissemination of ideas
 - Sharing of reagents and tools
 - Identifies solutions to problems or “bugs”
- Decreases need to re-invent
 - Facilitates collaborations and communities
- Less paperwork and bureaucracy
- Result: maximum rate of innovation and evolution

Make it fun

- “Play” vs. “work”
- We like to play with others
- We like to share accomplishments
- We like success
- We like to impress
- We like to win prizes
- Therefore: create a structure that fosters collaboration and competition

iGEM

iGEM Goals

- Enable the systematic engineering of biology
- Promote the open and transparent development of tools and reagents
- Help construct a society that can productively apply biological technology

The iGEM Challenge

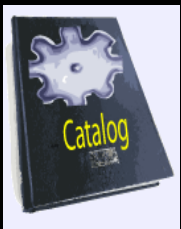
- Student-based
- Disseminate philosophy
- Inspire development of “cool” ideas
- Pool parts and expertise
- Promote sharing and community
- Encourage competition
- Require participation
- Drive results

Three pillars of iGEM



- **The iGEM wiki**

- Share philosophy, ideas, reagents, current info, news, biographies, stories, etc.



- **The Registry**


- Technical data, specifications, designs, test data, etc.



- **OpenWetWare**

- Transitions iGEM alumni to the synthetic biology professional community

iGEM Wiki




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iGEM - The international Genetically Engineered Machine competition


iGEM is an international arena where student teams compete to design and assemble engineered machines using advanced genetic components and technologies. [Learn more.](#)

**Meet the 37 teams participating in 2006**


**See teaching resources to learn about our unique methods**


**Ready to build? Go to the Registry for BioBrick parts and tools**


**The Ambassador Program helps teams around the globe succeed**

**Give and get help information and FAQs here.**

**iGEM Jamboree**

**Community Center**

**Current Events**

**Community News**

>> Jay Keasling - Scientist of the Year [Discover Magazine](#)

navigation

- [Main Page](#)
- [About iGEM](#)
- [Team Pages](#)
- [Ambassadors](#)
- [Teaching Resources](#)
- [OpenWetWare](#)
- [Jamboree](#)
- [Help!](#)

the registry

- [Registry](#)
- [About the Registry](#)

past/present/future years


- [Registration FAQ](#)
- [2006 New team FAQ](#)
- [iGEM History](#)

wiki related

- [Recent changes](#)
- [Help](#)
- [Community portal](#)

search

Registry



jump to part

navigation

- Main Page
- Browse Part Types
- iGEM Wiki
- Community portal
- Recent changes
- Recent part changes


resources


- User Accounts
- Add a Part
- Part Searches
- DNA Repositories
- Sequence Analysis
- Assembly Tool
- Help

search


article | discussion | edit | history

Registry of Standard Biological Parts







Browse Parts by Type




Browse Parts by School




iGEM 2006



Featured Parts



Help & Documentation







Users & Groups

Latest News

- [8/01/06] We have contact information for the creators of parts. You can access this information when you access "Hard Information" of a part.
- [8/01/06] A table made for [yeast parts](#) is now available on the [Part Types](#) page

Report any bugs [here](#) | Request new features [here](#) | See new features [here](#)































Registry Toolbox

-  **Add a part**
-  **Search Parts**
-  **DNA Repositories**
-  **Sequence Analysis**

Available Transcriptional Terminators

[Show 33 more parts](#)

[Edit](#)

-?-	Name	Description	Direction	Reversed Version	Biology	Efficiency * Fwd. Rev.		Length
 	BBa_B0011	Terminator (luxICDABEG, +/-)	Bidirectional	BBa_B0021	LuxIA	0.419	0.636	46
 	BBa_B0014	Terminator (B0012, B0011)	Forward	BBa_B0024	B0012, B0011	0.604		95
 	BBa_B0015	Terminator (B0010, B0012)	Forward	BBa_B0025	(B0010, B0012)	0.984	0.295	129
 	BBa_B0021	Terminator (luxICDABEG, +/-)	Bidirectional	BBa_B0011	LuxIA (reversed)	0.639	0.419	46
 	BBa_B0025	Terminator (Reverse B0015)	Reverse	BBa_B0015	(B0010, B0012) reversed	0.295	0.984	129
 	BBa_J52016	Eukaryotic terminator						238
 	BBa_B0010	Terminator (T1)	Forward	BBa_B0020	T1			80
 	BBa_B0012	Terminator (T7 TE)	Forward	BBa_B0022	T7 TE	0.309	-0.368	41
 	BBa_B0013	Terminator (T7 TE, +/-)	Bidirectional	BBa_B0023	T7 TE	0.6	-1.09	47
 	BBa_B0017	Terminator (B0010, B0010)	Forward		B0010, B0010			168
 	BBa_B0022	Terminator (Reverse B0012)	Reverse	BBa_B0012	T7 TE (reversed)	-0.368	0.309	41
 	BBa_B0023	Terminator (Reverse B0013)	Bidirectional	BBa_B0013	T7 TE (reversed)	-1.09	0.6	47
 	BBa_B0024	Terminator (Reverse B0014)	Reverse	BBa_B0014	(B0012, B0011) reversed		0.604	95
 	BBa_B1004	Terminator (artificial, small, %T~55)						34
 	BBa_J63002	yeast ADH1 terminator						225

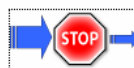
* Click here for terminator measurement information.

Part:BBa_B0011

Designed by Reshma Shetty

DNA Available
Experience Works

Entered: Antiquity

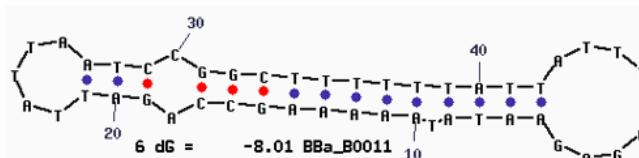
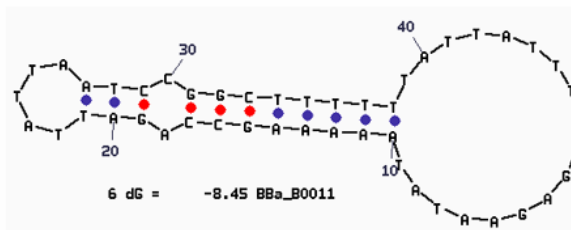


forward_efficiency 0.419
reverse_efficiency 0.636

Terminator (luxICDABEG, +/-)

- Bidirectional transcriptional terminator consisting of a 22 bp stem-loop.
- Appears to be a bidirectional terminator since it contains a string of T's on the direct strand after the stem loop and on the reverse strand before the stem loop. It is also found between two coding regions that point toward each other.

Secondary Structure



OpenWetWare



[article](#) [discussion](#) [view source](#) [history](#)

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Main Page



OpenWetWare is an effort to promote the sharing of information, know-how, and wisdom among researchers and groups who are working in biology & biological engineering. Learn more about us [here](#). If you would like edit access, would be interested in helping out, or want your lab website hosted on OpenWetWare, please let [us know](#).

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 Labs From around the world	 Protocols Share techniques & more	 Courses Host & view classes	 Groups Host & view organizations

News Highlights

 Science Writers Wanted	 BioSysBio 2007 Conference	 Video Highlight Crisanti Lab	 Lab Highlight Christophides Lab
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Media Spotlight



What's New

- 12/22: OpenWetWare welcomes it's 2000th [contributer](#)!
- 12/17: OpenWetWare mailing lists
[Join one](#) or [send email](#).

navigation

- Main Page
- Community portal
- Recent changes
- Random page

resources

- Materials
- Protocols
- Help

search

toolbox

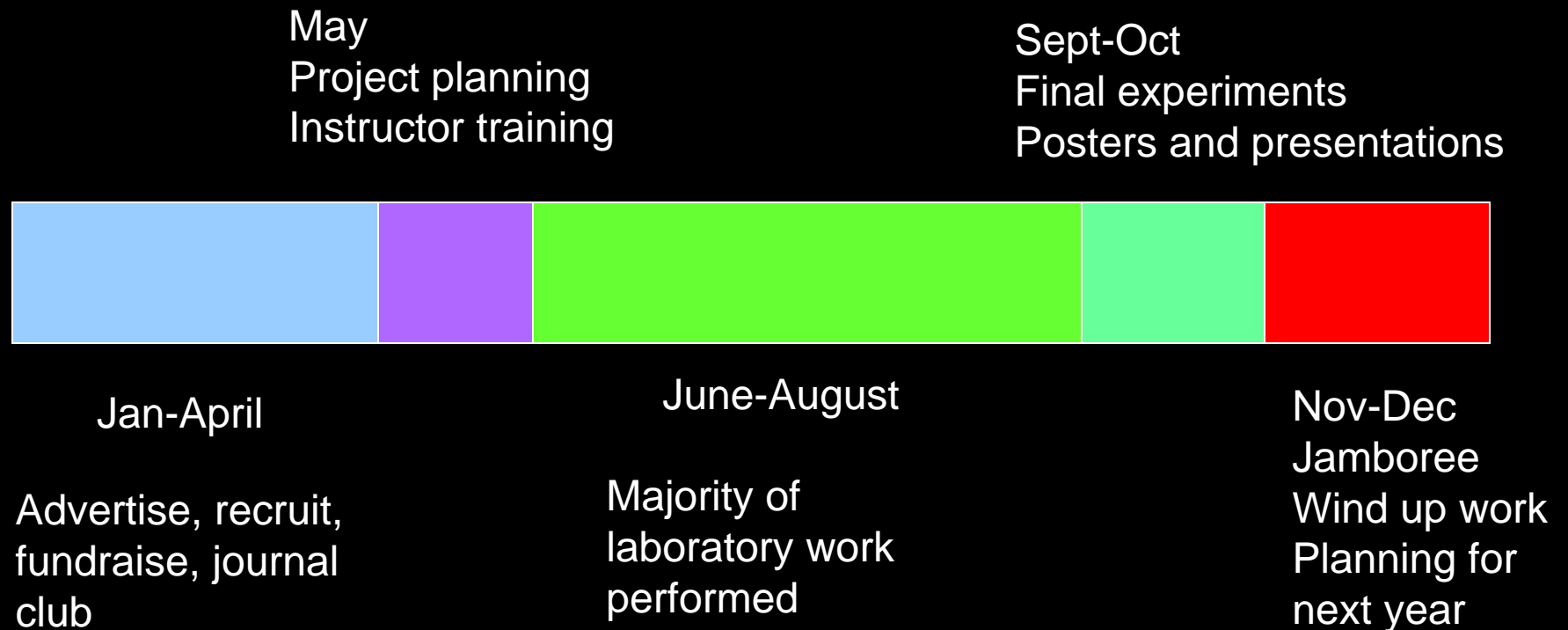
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
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 - Cite this article

Growth of iGEM

- Founded 2003 as MIT IAP
- 2004 – 5 teams, all US based, “friendly”, 75+
- 2005 – 13 teams, including Cambridge, Zurich, Canada, 175+



Timeline



Major Changes in '06

- Improved Registry (June) and iGEM wiki
- Shift to undergraduate focus
 - Great enthusiasm and able to take greater risks
- Formalized rules
 - Structured competition, qualifies for prizes
 - Unstructured competition, creates flexibility for unconventional teams, eg. high schools, to participate
- Ambassador program
 - Primarily for information exchange and technical support
- More documentation at all levels

International Genetically Engineered Machine Competition

© J. R. Brown, iGEM 2006

Global Distribution of Competing Teams





Africa



Arizona



Bangalore



Berkeley
[OWW [link](#)]



Boston



Brown



Calgary
[external [link](#)]



Cambridge
[external [link](#)]



Chiba



Chungbuk



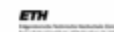
Davidson



Duke
[external [link](#)]



Edinburgh
[external [link](#)]



ETH Zurich



Freiburg



Harvard
[OWW [link](#)]

Imperial College
London

Imperial



Latin
America



Ljubljana,
Slovenia

McGill

McGill
[external [link](#)]
[(français) [link](#)]



Michigan



Mississippi
State



Missouri
Western



MIT
[OWW [link](#)]



IPN_UNAM,
México



Oklahoma



Penn State
[OWW [link](#)]



Prairie View



Princeton



Purdue



Rice



SF



Texas



Tokyo
Alliance



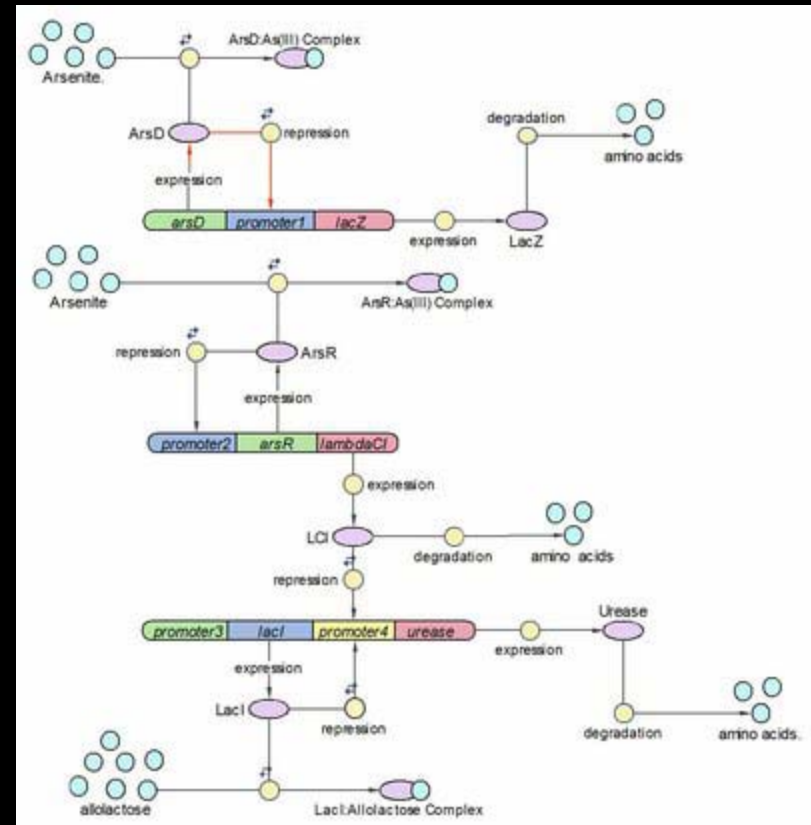
Toronto

Growth of iGEM

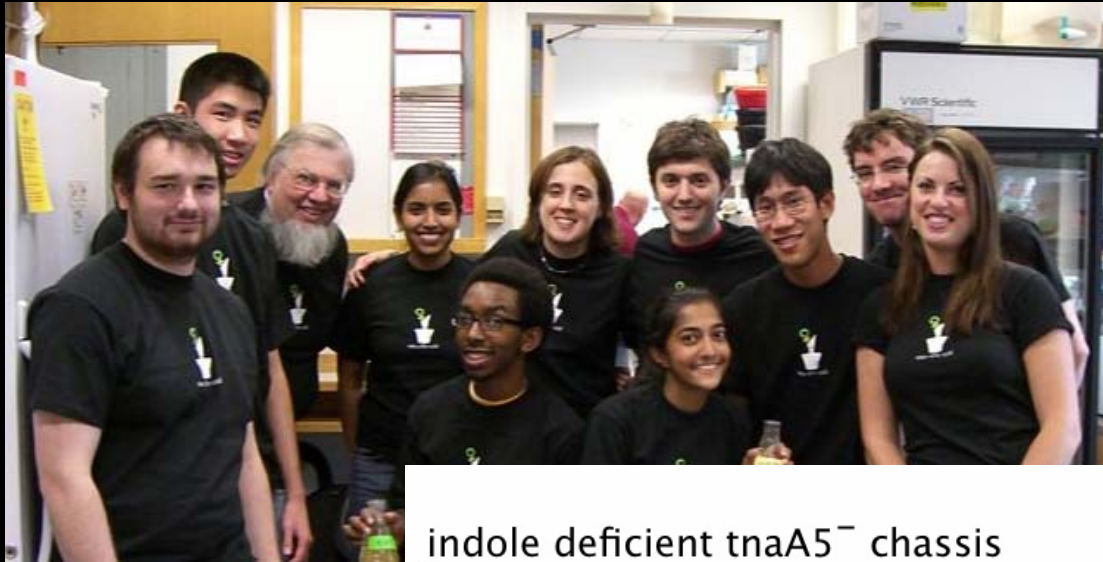
- 2006 – 37 teams, 15 countries, 450+
 - Sharp increase in global interest
 - 35,000 new hits on website since Jamboree
 - EU regional being established
 - China recruitment tour



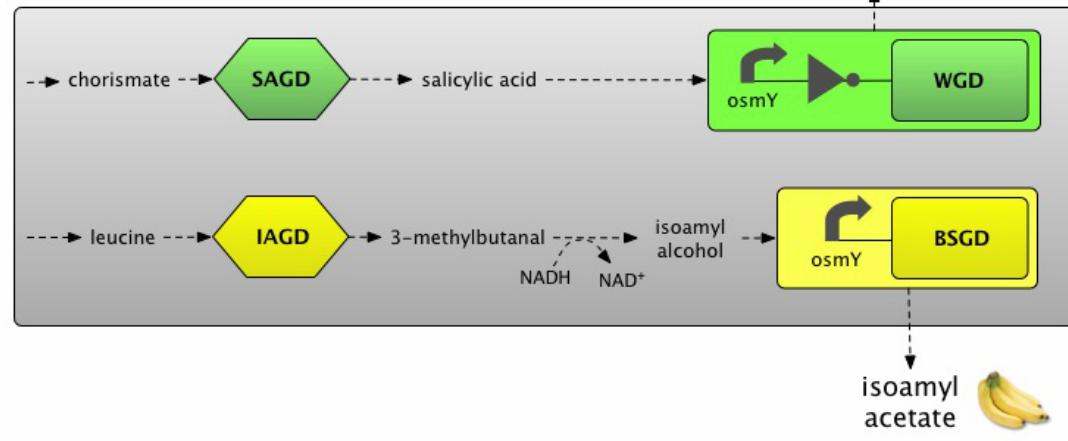
Arsenic biosensor



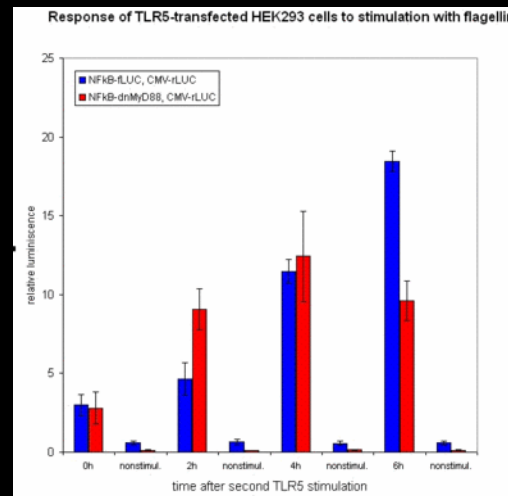
Smell Reporter system



indole deficient *tnaA5⁻* chassis



2006 Grand Prize Winner





Alberta January 2007

Early indicators of success

- Expanding collection of parts
- Large public interest
- Growing scientific interest
- Government recognition
- Extremely short development times
- Successful projects
- Publications
- Increasing financial support
- Low attrition – most participating schools return

Earlier this month, students from around the world locked horns in competition. Their challenge was to build functioning devices out of biological parts. **Erika Check** finds out how they got on.

Even if you're thinking big, you usually have to start small. Especially, as a group of Swiss students found, when big means counting to infinity. The team was drawing up a blueprint for the world's first counting machine made entirely of biological parts. Although they had their sights on loftier numbers, they opted to go no higher than two. If the plan worked, it would be a proof-of-principle for a much larger tallying device.

type for a much longer time, was one of the first to use the term "artificial intelligence" in the field of Technology (ETH) in Zurich, was one of 17 teams unveiling their projects at the first international Interlegiate Genetically Engineered Machine (iGEM) competition, held at the Massachusetts Institute of Technology (MIT) in Cambridge on 5 and 6 November. The event was the first time that students from different universities had been asked to design and build machines made entirely from biological components such as genes and proteins. They drew up grand designs for bacteria: Eels-a-Sketches, photosensitive 3-lights, thermometers and sensors. And if any of the designs succeeded completely, they would be because of the limitations of the nascent science of synthetic biology than any lack of enthusiasm, creativity or hard work.

Synthetic biology aims to merge engineering approaches with biology. Researchers working at the most basic level are copying simple biological processes, such as the production of a protein from a gene. They break the process down into its component elements, such as a gene and the pieces of DNA and other molecules that control its activity. They then string these elements together to build a module they know will behave in a particular way — say, oscillate between producing and not producing a protein, or produce a protein that can switch another module on or off.

It is these kinds of components — oscillators and switches — that engineers order from suppliers and link together to build more complex electronic circuits and machines. Synthetic biologists are trying to develop a similar armoury of biological components, dubbed BioBricks, that can be inserted into any genetic circuit to carry out a particular function. Scientists at MIT have established a Registry of Standard Biological Parts, a catalogue of BioBricks that theoretically

Compe
Much l
studen
iGEM
curios
to learn



Bidding for glory: teams from the ETH in Zurich (top), Cambridge, UK, (bottom right) and Massachusetts at the first International Intercollegiate GeneSically Engineered Machine competition.

selection of designs. Students from the University of Cambridge, UK, tried to make a circuit that could control the movement of *Escherichia coli* bacteria. They aimed to engineer the bacteria to contain a switch governing their sensitivity to the sugar maltose. With the switch off, the microbes would ignore the sugar. Tripping the switch would make the bacteria sensitive to

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to learn



By Carl Zimmer

Scientist of

day. Reading is developing ways to program DNA as easily as people program computers.



Engineering *Escherichia coli* to see light

These smart bacteria 'photograph' a light pattern as a high-definition chemical image

We have designed a bacterial system that is switched between two states by red light, and a system that allows a synthetic circuit to function that allows a lower of bacteria to function as a biological film, such that the projection of a pattern of light on to the bacteria produces a high-definition (about 100 megapixels per square inch), two-dimensional chemical image. This spatial control of bacterial gene expression could be used to 'print' complex biological materials, for example, and to investigate signalling pathways through precise spatial and temporal control of their phosphorylation steps.

Plants and some bacteria use a class of proteins called photoreceptors known as phytochromes to control phototaxis, photomorphogenesis and the production of protective pigments^{1,2}. Photoreceptors are not found in eukaryotes, such as *Escherichia coli*, so we created a light sensor that functions in *E. coli* by engineering a

A phytochrome is a two-component system that consists of a membrane-bound, extracellular sensor that responds to light and an intracellular response-regulator. The response-regulators of most phytochromes do not have DNA-binding domains and do not directly regulate gene expression, so we fused a cyanobacterial photoreceptor to an E. coli intracellular histidine kinase domain (Fig. 1, and see supplementary information). This design was based on the well studied E. coli EnvZ-OmpR two-component system, which normally regulates porin expression in response to osmotic shock³². The EnvZ histidine kinase domain has been used for the construction of functional chimeras³³, and a plant phytochrome has

The part of the photoreceptor that responds to light, phycoerythrobilin, is not naturally produced in *E. coli*. We therefore introduced two phycoerythrobilin-biosynthesis genes (*peb1* and *peb2*) from *Synechocystis* that convert haem into phycoerythrobilin* (partially from *DSM508*, BR, JGVCC, MIT, Germany).

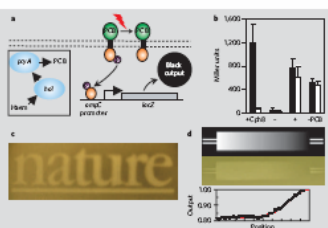


Fig. 1 Light imaging by using the *lacZ* reporter. **A**, The chromatin light receptor for Cph1 contains the photoreceptor *ErzZ* (green) and the histidine kinase and response-regulator from *ErzZ*-CmpII (or *ErzZ*-CmpI) (orange), covalent fusion of them to phytyl-acyl carrier protein (PCP), which forms a part of the photoreceptor. **B**, Light drives the source to a state which autophosphorylation is inhibited (right), turning off gene expression. For details of gene, see text. **C**, Miller assay showing that Cph1 is active in the dark (black line) in the presence of PCB as inducer in the light (white line). There are a light-dependent switch in the absence of PCB (**D**) and a light to constitutive activity when only the histidine kinase domain of *ErzZ* is expressed (**E**), or when the PCP-motif is constitutive pathway (**F**). **G**, The expression is projected on the surface of the cells. **H**, The expression of the *lacZ* reporter gene *lacZ*. **I**, Transient function of the circuit. At the intensity of the light is shown in the figure, the gradient provided from a 35-w laser, the circuit output gives a graded response.

the power and accessible methods available in synthetic biology. The principle regulation should be to spatially and temporally control individual cells and in potential application in regenerative medicine, manufacturing, materials, and the signalling networks.

Science students the world over share research



At MIT's International Genetically Engineered Machine Competition yesterday, the audience listened to a presentation on synthetic biology. (John Tlumacki/Globe Staff)



iGEM 2007

- On target for 100 teams, 1400 people
- Regional organizations are forming
- Podcasts, videos
- Expanding documentation
- Team portals
- Tighter competition rules
 - Some structure helped groups to create and meet goals

Reasons to participate in iGEM

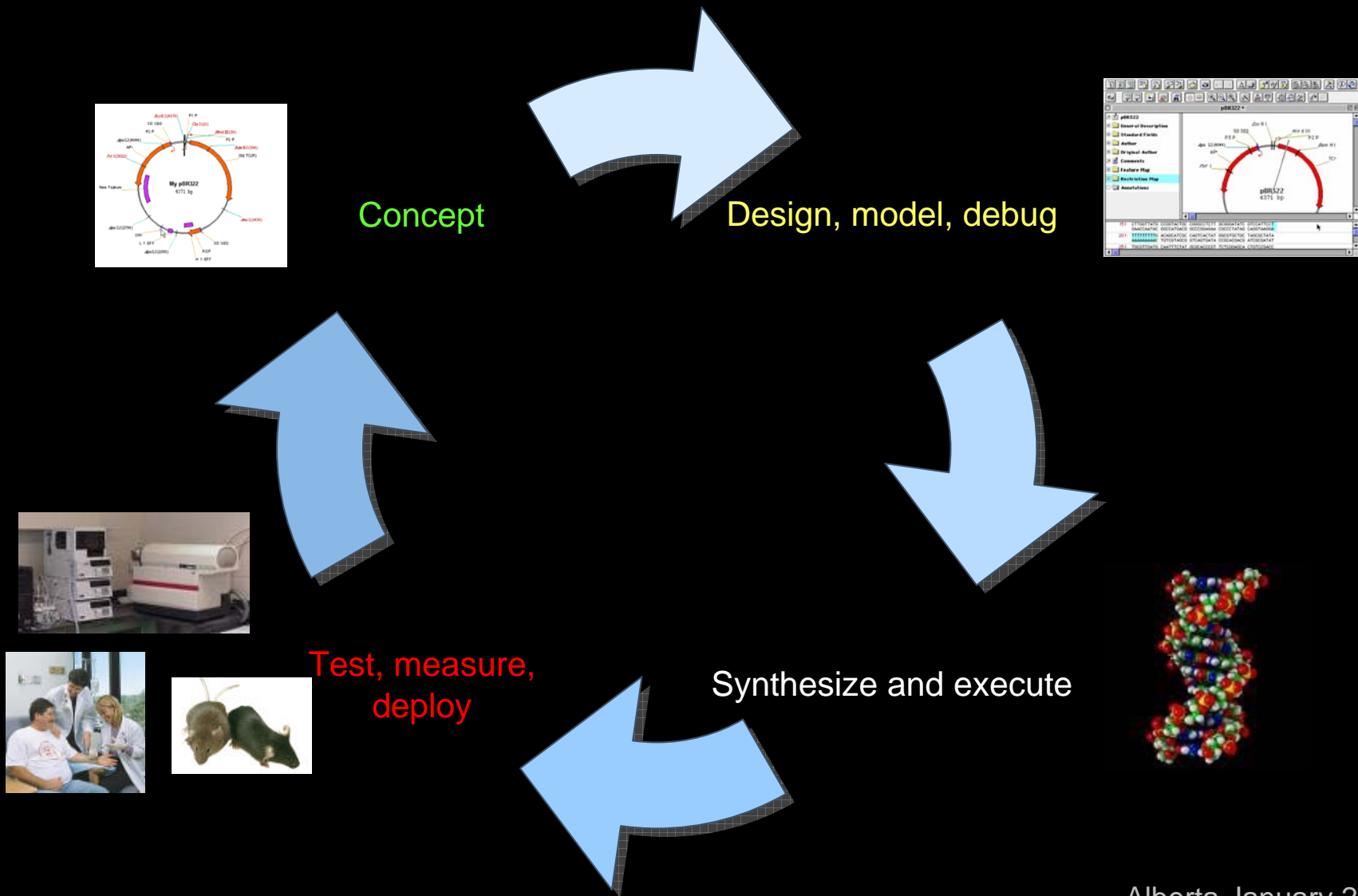
- Early opportunity to explore SB at low risk
- Access to top SB leaders worldwide
- Reach through to previous years' knowledge and parts (valued in \$M's) for relatively small investment
- Membership in a large and growing community
- High visibility
- Opportunities for funding
- Exposure to societal issues created by advanced biotechnologies
- Chance to demonstrate creativity, skills, and leadership
- Prizes and trophies

IGEM *is now recognized as the premier undergraduate educational program for synthetic biology*

Just the beginning...

- iGEM growth expected to stay strong
- DNA synthesis costs falling
- Synbio community growing quickly
 - Academia is re-tooling
- Synbio industry is budding
 - Codon Devices
 - Synthetic Genomics
 - Amyris
 - Coda

Synthetic biology workflow will become increasingly rapid and automated



Massive potential

Free your mind

- DNA code be used to make *anything* biological
- 100 million or more species in nature
- Given this proven biodiversity, the main barrier is our own creativity
- Entering a period of massive new speciation, driven by human wants and needs, and evolving at the rate of human technology (2x:18m)




Why is synbio still under the radar?

- If reverse engineering is science, then engineering is reverse science
- Scientists can find biological engineering counter-intuitive

Just as Lego has continued to evolve...

6167 6166 6163 6162 6161 5483 5482 4781 4780 628 626

6167 LEGO Deluxe Brick Box



WISH LIST SAVE PRODUCT SHOP CHECK PRICE

This deluxe set is ready for hours of creative play time and includes 2 mini-figures and many brick elements geared towards house and vehicle building—in a great storage box with transparent lid.

PRODUCT RATING 4 RATE THIS PRODUCT Based on 39 Ratings

Activities

DUPLO BRICKS DOWNLOADS WORLD BUILDER

Lots of fun building for small hands with DUPLO bricks.

Download wallpapers and screensavers.

Build cars and buildings to solve challenges and win.

LEGO education

Where to Buy Product Search

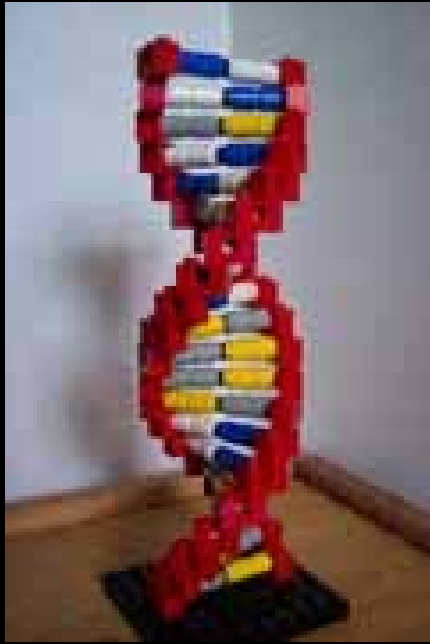
Preschool School Start Primary MINDSTORMS Education Centers About Us

Learning by Making

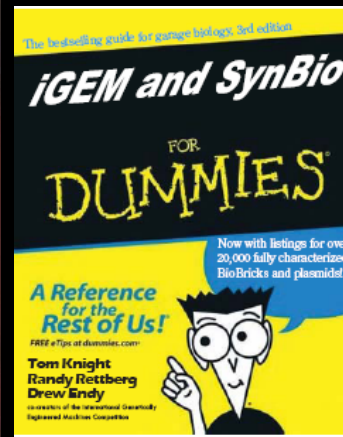
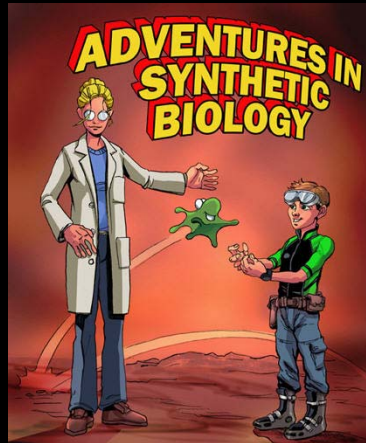
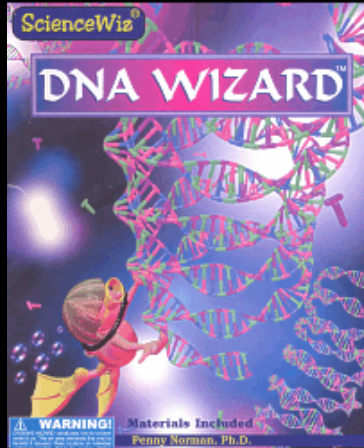
LEGO Education provides complete solutions designed to stimulate children's creativity, problem-solving and team-working skills. More than 25 years of experience has taught us the effectiveness of learning by actually making something. Our sets meet the goals for early childcare practitioners and are highly relevant in schools as well as in after-school environments.

Customer Service About Us Educators Parents LEGOLAND Site Index Legal Notice

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So will iGEM and synthetics



- Applied by younger scientists
- Synthetic bacteria, other organisms
- Biotech 2.0



However...



“With great power comes great responsibility”

“We scare people” – Endy 11/06

If iGEM and synbio are to thrive, we must *continually reinforce the positive applications* of this technology

Thank you